

PRELIMINARY AMENDMENT
ATTORNEY DOCKET NO. Q57834
US Appln. No.: 09/497,515

14.(Amended) A method of manufacturing an electrode for a fuel cell comprising the
steps of:

A50
preparing an electrode (j) comprising a catalyst layer containing a solid polymer
electrolyte and catalyst particles;
preparing a solution (c) in which a polymer (a) is dissolved in a solvent (b);
allowing said solution (c) to be contained in said electrode; and
extracting said solvent (b) from the said solution (c) with a non solvent (d) which is
insoluble in said polymer (a) and miscible with the solvent (b).

A51
20. (Amended) The method according to claim 13, 14, 17 or 18, further comprising
the step of: fluorinating said porous polymer.

REMARKS

The above amendment corrects errors caused by translation of the specification from
Japanese to English and by printer error. No new matter is added. Entry and consideration of
this Amendment is respectfully requested.

Respectfully submitted,

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APPENDIX
VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

The specification is changed as follows:

Page 1 bridging page 2, 4th paragraph:

As shown in Fig. 8, the electrode of a fuel cell incorporates a porous catalyst layer 86 in which catalyst particles 81 and solid polymer electrolyte 82 are distributed three-dimensionally with a plurality of small pores 84 are formed; and a gas diffusion layer 88 containing a electro-conductive porous substance substrate 87.

Page 2, 2nd paragraph:

On the other hand, the catalyst particles 81 of the catalyst layer 86 form electron conductive channel, the solid polymer electrolyte 82 forms a proton conductive channel and the small pores 84 form supply/discharge channel for supplying oxygen or hydrogen to the inside from the surface of the catalyst layer 86 and discharging water produced in the cathode to the surface ~~for~~ from the inside of the catalyst layer. The three channels are three-dimensionally dispersed in the catalyst layer 86 so that an infinite number of three-phase boundary sites, in which the gas, protons (H⁺) and electrons (e) are supplied and receipted simultaneously, are formed in the catalyst layer 86. Thus, portions for the reaction sites of the electrode is provided.

Page 3, 2nd paragraph:

The solid polymer electrolyte fuel cell has the catalyst layer with the pores forming three-dimensional channel for supplying oxygen or hydrogen. Therefore, the humidified supply gas, which is the reactant, causes water to be accumulated in the surface of the catalyst layer. As an alternative to this, accumulation of water in the pores inhibits supply of

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the reactant gases to the three-phase boundary sites of the catalyst layer, and, in particular, to the deep portion of the electrode. Thus, an actual active surface area is reduced. Therefore, the performance of the cell cannot satisfactorily be obtained. Accordingly, adequate hydrophobicity is imparted to the gas diffusion layer containing the electro-conductive porous substance substrate and the catalyst layer to prevent accumulation of water.

Page 3, 3rd paragraph:

The Importance of hydrophobicity to the electro-conductive porous substance substrate in a case of carbon paper (having a thickness of 1.5 mm) which is made by a sintering body of carbon fibers will now be described. The carbon paper is immersed in solution of PTFE suspension. Then, the carbon paper containing the PTFE particles are baked at about 350°C for 15 minutes in a nitrogen atmosphere so that the surfaces of the carbon fibers are coated with PTFE.

Page 4, 2nd paragraph:

The hydrophobicity of both of the catalyst layer and the electro-conductive porous substance substrate is, however, unsatisfactory at present. Supply of hot and enough humidified gases to improve the proton conductivity of the ion-exchange membrane resulting in enhancement of cell power unsatisfactorily causes water to be water flooding accumulated in the pores of the catalyst layer and the surface of the same. As a result, supply of the reactant gases to the three-phase boundary sites of the catalyst layer, and, in particular, to deep portions of the catalyst layer is inhibited. As a result, the actual active surface area is reduced, causing a problem to arise in that the performance of the cell cannot sufficiently be obtained. In particular, because water is produced with the reactions proceeding, this accumulation of water is occurred easily in the pores of the catalyst layer in the cathode.

Page 5, 2nd paragraph:

To furthermore improve the hydrophobicity of the electro-conductive porous substance substrate, the amount of PTFE suspension which is applied to the electro-conductive porous substance substrate must be increased. If the amount of it is enlarged excessively, PTFE particles close pores of the electro-conductive porous substance substrate.

In the foregoing case, there arises a problem in that gas supply is inhibited.

Page 5, 3rd, paragraph:

In general, it is said that the effective thickness of the catalyst layer for the electrochemical reactions is 5 $\text{m } \mu\text{m}$ to 10 $\text{m } \mu\text{m}$. The gas supply in the electrode cannot sufficiently be performed in the catalyst layer having a larger thickness. As a result, the gas is wasted and the function of the electro-conductive porous substance substrate for maintaining the passage for the gas is inhibited. Therefore, control of the thickness of the catalyst layer is an important factor to improve the performance of the electrode.

Page 6 bridging page 7, 3rd paragraph:

SUMMARY OF THE INVENTION

In view of the foregoing, an object of the present invention is to advance the performance of an electrode for a fuel cell by improving the hydrophobicity while a gas diffusivity of the gas diffusion electrode for a fuel cell is being maintained. Another object of the present invention is to improve the performance of an electrode for a fuel cell by densely forming a electro-conductive porous substance substrate to uniform the thicknesses of the catalyst layer while a gas diffusivity of the gas diffusion layer is being maintained.

Page 7, 1st paragraph:

According to the present invention, an electrode for a fuel cell comprises a catalyst layer containing a solid polymer electrolyte, catalyst particles and porous polymer (a)

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alternatively, an electrode for a fuel cell comprises a catalyst layer containing a solid polymer electrolyte and catalyst particles, wherein porous polymer is provided for the inside portions of pores of the catalyst layer or/and the surface of the catalyst layer. An electrode for a fuel cell comprises a catalyst layer containing a solid polymer electrolyte and catalyst particles; and a gas diffusion layer containing electro-conductive porous ~~substance~~ substrate, wherein the catalyst layer or/and electro-conductive porous ~~substance~~ substrate incorporate porous polymer. It is preferable that the porous polymer is fluorocarbon polymer.

Page 9, 1st paragraph:

As shown in Figs. 4, 5 and 6, a catalyst layer according to the present invention ~~and~~ ~~containing~~ comprises a solid polymer electrolyte and catalyst particles and plural ~~porous~~ ~~catalyst layer pores~~. The catalyst layer has a structure that catalyst particles 41, 51 and 61 and solid polymer electrolytes 42, 52 and 62 are distributed three-dimensionally with a plurality of small pores 43, 53 and 63 in the catalyst layer. The average diameter of the small pore is from 10nm to 1μm. Basically, the catalyst particles form an electron conductive channel and the pores for a channel for supplying and discharging oxygen or hydrogen and water which is a product.

Page 9 bridging page 10, 2nd paragraph:

In the case of the electrode for a fuel cell shown in Fig. 4, porous polymer 44 with three-dimensional network pore (hereinafter referred to as "porous polymer") exist mainly at the small pores in the catalyst layer. The electrode for a fuel cell shown in Fig. 5 includes porous polymer 54 with three-dimensional network pore at the surface of the catalyst layer. An electrode for a fuel cell shown in Fig. 6 includes porous polymer 64 with three-dimensional network pore existing at both the small pores and the surface of the catalyst layer. If necessary, each of the foregoing electrodes for fuel cells are able to ~~incorporate~~

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include the catalyst layer and the gas diffusion layer with the electro-conductive porous substance substrate with the porous polymer at same time. Referring to the figures above, reference numerals 45, 55 and 65 represent ion-exchange membranes and each of 46, 56 and 66 represents a carbon porous material made by sintering of carbon fibers as an electro-conductive substrate. If necessary, PTFE particles may be provided into the catalyst layer similarly to the conventional technique.

Page 10, 2nd paragraph:

Although the effect of the present invention can be obtained when the porous polymer is provided for only the inside portions of the pores as shown in Fig. 4 or when the porous polymer is provided for only the surface as shown in Fig. 5, a furthermore satisfactory activation can be realized when the porous polymer is provided for both of the inside of the small pores and the surface of the catalyst layer as shown in Fig. 6.

Page 11, 2nd paragraph:

Fig. 7 is a schematic view showing the structure of an electrode for a fuel cell according to the present invention, incorporating which comprises a catalyst layer, containing a solid polymer electrolyte and catalyst particles, and a gas diffusion layer, containing the electro-conductive porous substance substrate, the structure being characterized in that the electro-conductive porous substance substrate includes the porous polymer. Referring to Fig. 7, reference numeral 71 represents a catalyst layer of the electrode, 72 represents the electro-conductive porous substance substrate such as carbon paper or carbon cloth and 73 represents the porous polymer. Since the electro-conductive porous material according to the present invention includes the porous polymer in the pores thereof, a dense structure can be formed. Therefore, the thicknesses of the catalyst layer of the electrode can substantially be uniformed.

Page 13, 1st paragraph:

To realize smooth supply and discharge of the reactant gases, it is preferable that the small pores in the porous polymer are continuous three-dimensionally network structure such as shown in Fig. 10. As for the diameter of each pore, it is preferable that the average diameter of the pores is 1 μm or smaller, more preferably 0.5 μm or smaller, preferably 100nm or larger. Because average diameter of pores in electro-conductive substrate is about 10 μm to 20 μm . Furthermore, it is preferable that the average diameter of pores in porous polymer is 0.05 μm or smaller, because average diameter of pores in catalyst layer is about 1 μm to 2 μm . It is preferable that the porosity of the porous polymer is not lower than 45 % nor higher than 95 % from a viewpoint of realizing smooth supply of gases and smooth discharge of water.

Page 13 bridging page 14, 3rd paragraph:

For example, the phase inversion occurs, by a method using change in the solubility of polymer (a) with lowering the temperature of the solution (c) in a case of combination of the polymer (a) and the solvent (b) such that the polymer (a) cannot easily be dissolved in the solvent (b) at low temperature and the polymer (a) can be dissolved when the temperature has been raised will now be described. The phase inversion is a phenomenon that the polymer (a) with respect to the solvent (b) becomes supersaturated when the polymer (a) has completely been dissolved in the solvent (b) by raising the temperature followed by lowering the temperature of the solution (c) so that the polymer (a) and the solvent (b) are separated from each other with decreasing the solubility. Therefore, the porous polymer can be obtained.

Page 16, 2nd, paragraph:

When the porous fluorocarbon polymer is prepared as a polymer (a) by the phase inversion process using the above-mentioned solvent extraction method, dense and uniform

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pores can be formed. Therefore, it is preferable that the polymer (a) is polyvinylidene fluoride (PVdF), and P(VdF) copolymer, such as vinylidene fluoride /hexafluoropropylene copolymer (P (VdF-HFP) or vinylidene fluoride-ethylene tetrafluoride (P (VdF-TFP). In particular, it is preferable for polymer (a) that polyvinylidene fluoride (PVdF) exhibiting excellent hydrophobicity or vinylidene fluoride /hexafluoropropylene copolymer (P (VdF-HFP) which is a soft material which permits easy handling is employed.

Page 17, 1st paragraph:

The solvent (b) for dissolving the polymer (a) is required to dissolve the polymer (a). The material is exemplified by ester, such as propylene carbonate, ethylene carbonate, dimethyl carbonate, diethyl carbonate or ethylmethyl carbonate; ether, such as dimethyl ether, diethyl ether, ethylmethyl ether or tetrahydrofuran (THF); ketone, such as methylethyl ketone or acetone; dimethylformamide; dimethyl acetoamide; 1-methyl-pyrollidone; and N-methylpyrrolidon (NMP).

Page 17, 3rd paragraph:

When the foregoing materials are employed in the solvent extraction method, it is preferable that polymer (a) is polyvinylidene fluoride (PVdF) or P (VdF-HFP), and solvent (b) is in N-methylpyrrolidon (NMP), and non solvent (d) is water or the mixed solution of water and alcohol from a viewpoint of obtaining excellent hydrophobicity and uniform diameters of the pores.

Page 17 bridging page 18, 4th paragraph:

A method of manufacturing the electrode for a fuel cell according to the present invention and structured as described above will now be described. Paste for the catalyst layer ~~consisting of~~ comprises catalyst supported on carbon particles, the solid polymer electrolyte solution and, if necessary, PTFE suspension is applied onto a polymer film to

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form a film of the paste (in general, having a thickness of 3 μm to 30 μm). Then, heating and drying are performed so that the conventional catalyst layer can be obtained. As an alternative to this, paste of the catalyst layer ~~consisting of~~ comprising catalyst supported on carbon particles (noble metal particles, such as platinum, are highly dispersedly loaded on carbon particle) and, if necessary, ~~solution~~ PTFE suspension is applied onto the polymer film to form a film of the paste (in general, having a thickness of 3 μm to 30 μm). Then, heating and drying are performed. Then, the solid polymer electrolyte solution is applied and allowed to be impregnated from a position above the ~~polymer~~ film of the paste. Thus, the conventional catalyst layer can be obtained. If necessary, these above-mentioned conventional catalyst layers are joined to the ion-exchange membrane. After that, if necessary, the gas diffusion layer including electro-conductive porous substrate is joined to the surface of the catalyst layer. Then, the solution (c) in which the polymer (a) is dissolved in the solvent (b) is contained in the above-mentioned conventional catalyst layer. Then, the polymer (a) is separated from the solution (c) by phase inversion process so that the catalyst layer including porous polymer for a fuel cell's electrode is obtained. For example, catalyst layer including the solution (C) is immersed into the non solvent (d) which is insoluble in polymer (a) and soluble in the solvent (b). Thus, the catalyst layer for a fuel cell's electrode can be obtained by solvent extraction method. Then, the polymer (a) is phase-separated from the solution (c) so that the electrode for a fuel cell is obtained. As an alternative to this, the solution (c) in which the polymer (a) is dissolved in the solvent (b) is contained by coating or immersion. Then, the non solvent (d) which is insoluble in polymer (a) and soluble in the solvent (b) is substituted for the polymer (a). Thus, the electrode for a fuel cell can be obtained by solvent extraction method.

Page 19, before the 1st paragraph please insert the following new paragraph:

These above-mentioned catalyst layers are adopted as an electrode. Before that, if necessary, those are joined to the gas diffusion layers containing electro-conductive porous substrate.

Page 19, 1st paragraph:

As an alternative to this, paste of the catalyst layer ~~consisting of comprising~~ catalyst supported on carbon particles, the solid polymer electrolyte solution and, if necessary, PTFE suspension is applied onto an electro-conductive porous ~~substance~~ substrate to form a film of the paste (in general, having a thickness of 3 μm to 30 μm). Then, heating and drying are performed so that the conventional electrode is manufactured. As an alternative to this, paste of the catalyst layer ~~consisting of comprising~~ catalyst supported on carbon particles (noble metal particles, such as platinum, are highly dispersedly loaded on carbon particle) and, if necessary, PTFE suspension is applied onto electrdo-conductive porous substrate to form a film of the past (in general, having a thickness of 3 μm to 30 μm). Then, heating and drying are performed. Then, the solid polymer electrolyte solution is applied and allowed to impregnate so that the conventional electrode is manufactured. If necessary, these above-mentioned conventional electrode are joined to the ion-exchange membrane.

Page 20, 1st paragraph:

When the latter manufacturing method is employed, the electrode for a fuel cell, ~~consisting of comprising~~ the catalyst layer containing the solid polymer electrolyte and the catalyst particles and the gas diffusion electrode containing the electro-conductive porous ~~substance~~ substrate, has the structure that both the catalyst layer and the electro-conductive porous ~~substance~~ substrate contain the porous polymer. Therefore, an electrode for a fuel cell exhibiting high activity can be manufactured. When fluorocarbon polymer exhibiting

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excellent hydrophobicity is employed, a necessity for previously imparting the hydrophobicity to the electro-conductive porous substance substrate can be eliminated. Because in the foregoing case, the porous polymer provided for the electro-conductive porous substance substrate acts as a hydrophobic material.

Page 21 bridging page 22, 3rd paragraph:

Then, a method is employed with which paste of the catalyst layer including catalyst supported on carbon particles, the solid polymer electrolyte solution and, if necessary PTFE (polytetrafluoroethylene) suspension is applied ~~onto~~ on the electro-conductive porous substance substrate by a brush or by spraying is employed. As an alternative to this, a film of the paste of catalyst layer is directly formed on the surface of the electro-conductive porous substance substrate by a screen printing method or a doctor blade method. As an alternative to this, a method may be employed with which a catalyst layer formed on a polymer film or metallic foil as a blank is transferred to the electro-conductive porous substance substrate by a hot press method or the like and then the blank is removed away. As an alternative to this, a method may be employed with which the catalyst layer is joined to the surface of the ion-exchange membrane by the foregoing method or the like. Then, the electro-conductive porous substance substrate including the porous polymer provided for the surface of catalyst layer thereof is hot-pressed or pressed.

Page 22, 1st paragraph:

If the method of manufacturing an electrode of the present invention for a fuel cell is used which is characterized in that when the porous polymer contains fluorocarbon polymer, furthermore excellent hydrophobicity can be obtained by fluorination of the fluorocarbon polymer ("fluorination of the fluorocarbon polymer" is substitution of a fluorine atom for another atom for example, a hydrogen atom or a chlorine atom)carbon polymer.

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Fluorocarbon polymer includes polytetrafluoroethylene or ~~tetrafluoroethylene-hexafluoropropylene~~ (PTFE) or tetrafluoroethylene-hexafluoropropylene copolymer (EPE) which consists of only both carbon atoms and fluorine atoms. Since the foregoing material cannot furthermore be fluorinated, the foregoing materials are omitted from the scope of the present invention. It is preferable that the ~~fluoropolymer~~ fluorocarbon polymer that is polymer containing such as polychlorotrifluoro ethylene ~~copolymer~~ (PCTFE), polyvinylidene fluoride (PVdF) or polyvinylidene fluoride (PVF), vinylidne fluoride/hexafluoropropylene copolymer P(VdF/HFP), ethylene-tetrafluoroethylene copolymer (ETFE) or ethylene-chlorotrifluoroethylene copolymer (ECTFE). Their mixtures may be employed.

Page 23, 1st paragraph:

The process for fluorination of the porous fluorocarbon polymer is performed by substitution fluorine (F) for another atom, such as hydrogen (H) or chlorine (Cl), joined to carbon skeletons of the fluorocarbon polymer. For example, when the porous fluorocarbon polymer is exposed to fluorine gas, the foregoing process can be performed while the porosity is being maintained. When the substitution ratio of fluorine (F) of the ~~fluorocarbon~~ fluorine polymer for another atom, such as hydrogen (H) and chlorine (Cl), is adjusted by change in contact time between fluorocarbon resin and fluorine gas, the hydrophobicity can be controlled. Although fluorocarbon polymer has somewhat hydrophobicity, the process for furthermore fluorinating fluorination of the fluoro carbon polymer as described above enables higher hydrophobicity to be obtained.

Page 23, 3rd paragraph:

Paste of a catalyst layer composed of platinum supported on carbon (10V30E: 30wt%Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku) and solid polymer electrolyte solution (5 wt% Nafion solution manufactured by Ardrich) was applied

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to the surface of a porous carbon sheet paper(0.5 mm) as an electro-conductive porous substrate to form the film of the paste. Then, the paste was dried at 120°C for one hour in a nitrogen atmosphere. Thus, a conventional an electrode was obtained. The electrode was impregnated with PVdF/NMP solution (the concentration of PVdF: 15 wt%) in a vacuum, and then immersed in water for 10 minutes. Thus, electrode A for a fuel cell was obtained.

Page 24, 1st paragraph:

The electrode A has a structure that the porous PVdF is provided for the inside portions of pores and the surface of the catalyst layer, inside of the electro-conductive porous substance substrate.

Page 24, 3rd paragraph:

Then, the electrode A was hot-pressed to both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C. Then, this membrane- electrode assembly was introduced into a single fuel cell holder so that cell A was obtained.

Page 24 bridging page 25, 4th paragraph:

Paste composed of comprising platinum supported on carbon (10V30E: 30wt% Pt; supported on Valcan XC-72 manufactured by Tanaka Kikinzoku) and solid polymer electrolyte solution (5 wt% Nafion solution manufactured by Ardrich) was applied onto a polymer film (PFA) as a blank to form the film of the paste. Then, the paste was naturally dried for about one hour so that a catalyst layer was formed. The catalyst layer was hot-pressed to both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C, and then the blank was removed away. Thus, a membrane-catalyst layer assembly was manufactured. Then, the surface of the catalyst layer of the assembly was coated with

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assembly was immersed in water for 10 minutes so that a membrane-catalyst layer assembly B was manufactured.

Page 25, 3rd paragraph:

A porous carbon papers (0.5 mm), which served as a gas diffusion layer and to which hydrophobicity was imparted, were hot-pressed to the surface of the each catalyst layer. Then, the assembly was introduced into a single fuel cell holder so that cell B was manufactured.

Page 25, 4th paragraph:

Paste ~~composed of~~ comprising platinum supported on carbon (10V30E: 30wt%Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku), solid polymer electrolyte solution (5 wt% Nafion solution manufactured by Ardrich) and PTFE suspension (Teflon 30J manufactured by Mitsui-Dupont Fluorochemical) was applied onto a hydrophobic porous paper (0.5 mm) as an electro-conductive porous substrate to form a film of the paste. Then, the paste was dried for about one hour at 120°C in a nitrogen atmosphere so that electrode C for a fuel cell was obtained.

Page 26, 2nd paragraph:

Then, the electrode C was hot-pressed to both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μ m) at 140°C. Then, the membrane-electrode assembly was introduced into a single fuel cell holder so that cell C was manufactured.

Page 26, 3rd paragraph:

Paste ~~composed~~ comprising of platinum supported on carbon (10V30E: 30wt%Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku), solid polymer electrolyte solution

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(5 wt% Nafion solution manufactured by Ardrich) and PTFE suspension (Teflon 30J manufactured by Mitsui-Dupont Fluorochemical) was applied onto a polymer film (PFA) as a blank to form the film of the paste. Then, the paste was naturally dried for about one hour so that a catalyst layer was manufactured. Then, the catalyst layer was hot-pressed to both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C and then the blank was removed away so that membrane-catalyst layer a assembly D was manufactured. The amount of the platinum in the paste was adjusted when the paste was prepared so that the amount of platinum in both sides of assembly D was about 1.0 mg/cm².

Page 27 bridging page 28, 3rd paragraph:

As can be understood from Fig. 1, the cells (A and B) according to the present invention exhibited higher output voltages at each current density as compared with the conventional cells C and D. In particular, the cell A structured such that porous PVdF was provided for the inside portions of the pores in the catalyst layer and the surface of the same exhibited an output higher than that of the cell B. Since the electrode according to the present invention has the structure that the porous PVdF exhibiting high hydrophobicity was provided for the inside portions of the pores in the catalyst layer and/or the surface of the same, supply of hydrogen and oxygen as reactants to the deep portions of the electrode was enabled. Therefore, an active area of the catalyst layer was larger than that of the conventional catalyst layer. In particular, the cell A' having the structure that porous PVdF was provided for the inside portions of the pores of the catalyst layer and the surface of the same and inside of the carbon paper as the substrate, exhibited excellent characteristics.

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Page 28, 1st paragraph:

A porous carbon substrate (the thickness was 0.5 mm, an average fiber diameter was 10 μm , an average diameter of pores was 10 μm and the porosity was 75 %) was, in a vacuum, impregnated with PVdF/NMP solution (concentration of PVdF was 20 wt%). Then, the substrate was immersed in water for 10 minutes so that the porous carbon substrate including the porous PVdF was manufactured.

Page 28, 2nd paragraph:

Then, paste ~~composed of~~ comprising platinum supported on carbon (10V30E: 30wt% Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku), solid polymer electrolyte solution (5 wt% Nafion solution manufactured by Ardrich) and PTFE suspension (Teflon 30J manufactured by Mitsui-Dupont Fluorochemical) was applied onto the surface of the above-mentioned porous carbon substrate by ~~performing~~ a spraying method so that electrode E for a fuel cell was manufactured.

Page 28, 4th paragraph:

The electrode E was hot-pressed to both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C. This membrane-electrode assembly was introduced into a single fuel cell holder so that cell E was manufactured.

Page 29, 1st paragraph:

A porous carbon paper as a substrate (the thickness was 0.5 mm, an average fiber diameter was 10 μm , an average diameter of pores was 10 μm and the porosity was 75 %) was impregnated with P(VdF-HFP)/MEK solution (the concentration of PVdF-HFP was 10 wt%) at 75°C. Then, the substrate including P(VdF-HFP)/MEK solution was dry in

thermostatic oven at 30°C so that MEK was removed. Thus, the porous carbon substrate including the porous P(VdF-HFP) was manufactured by the phase inversion process.

Page 29, 4th paragraph:

The electrode F was hot-pressed to both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm). This membrane-electrode assembly was introduced into a single fuel cell holder so that cell F was manufactured.

Page 30, 1st paragraph:

A porous carbon substrate (the thickness was 0.5 mm, an average fiber diameter was 10 μm , an average diameter of pores was 10 μm and the porosity was 75 %), to which hydrophobicity was imparted with PTFE suspension, ~~was dispersed~~ was applied with paste ~~composed of~~ comprising platinum supported on carbon (10V30E: 30wt% Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku), solid polymer electrolyte solution (5 wt% Nafion solution manufactured by Ardrich) and PTFE suspension (Teflon 30J manufactured by Mitsui-Dupont Fluorochemical) by a spraying method so that electrode F for a fuel cell was manufactured.

Page 30, 3rd paragraph:

The electrode F was hot-pressed onto both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C. The membrane-electrode assembly was introduced into a single fuel cell holder so that cell G was manufactured.

Page 30 bridging page 31, 4th paragraph:

I-V characteristics of the cells (E, F and G) on H₂/O₂ were measured. The I-V characteristics for the cell (E) and cell (G) were shown in Fig. 2. Note that the I-V

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characteristics of the cell (F) according to the present invention were similar to those of the cell (E) according to the present invention. The operation conditions were such that the pressure of supplied gases were 1.8 atm ~~pressures~~. Moreover, humidification of gases was carried out by bubbling in a closed water tank ~~set to~~ at 85°C to perform wetting. Each cell was operated at 78°C. Each current level was maintained for 5 minutes during the measurement.

Page 31, 1st paragraph:

As can be understood from Fig. 2, the cells (E and F) according to the present invention exhibited higher output voltage at each current density as compared with the conventional cell (G). Since the conventional electrode had the structure that the thickness of the catalyst layer was uniform, so ineffective portions were distributed in the catalyst layer. On the other hand, each of the electrodes according to the present invention had the structure that the thickness of each of the catalyst layer of the electrode was controlled to be constant (5 μm to 10 μm). Therefore, the overall portion of the catalyst layer acted effectively so that the electrochemically active area of the catalyst layer of the electrode was larger than that of the conventional catalyst layer of the electrode.

Page 31 bridging page 32, 2nd paragraph:

A porous carbon paper as a substrate (the thickness was 0.5 mm, an average fiber diameter was 10 μm , an average diameter of pores was 10 μm and the porosity was 75 %) was, in vacuum, impregnated with 20wt% P(VdF-HFP)(HFP: 6 wt%)/NMP solution. Then, the substrate including P(VdF-HFP)/NMP solution was immersed in water for 10 minutes so that a porous carbon substrate including the porous P(VdF-HFP) was obtained. Then, the porous carbon substrate was exposed in to a mixed-gas atmosphere in which 10% fluorine gas - 90% nitrogen gas for 20 minutes. Thus, carbon substrate including a porous carbon

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was, in vacuum, impregnated with 20wt% P(VdF-HFP)(HFP: 6 wt%)/NMP solution. Then, the substrate including P(VdF-HFP)/NMP solution was immersed in water for 10 minutes so that a porous carbon substrate including the porous P(VdF-HFP) was obtained. Then, the porous carbon substrate was exposed ~~in-to~~ a mixed-gas atmosphere in which 10% fluorine gas - 90% nitrogen gas for 20 minutes. Thus, carbon substrate including a porous carbon substrate including the fluorinated porous fluorocarbon polymer P(VdF-HFP) was manufactured. Then, paste composed of platinum supported on carbon (10V30E: 30wt% Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku), solid polymer electrolyte solution (5 wt% Nafion solution manufactured by Ardrich) and ~~solution~~ PTFE suspension (Teflon 30J manufactured by Mitsui-Dupont Fluorochemical) was applied onto the porous carbon substrate to form the film of the paste so that electrode H for a fuel cell was manufactured. The amount of the platinum supported on carbon was adjusted when the paste was prepared so that the amount of platinum loading in the electrode H was about 1.0 mg/cm².

Page 32, 1st paragraph:

The electrode H was hot-pressed onto both sides of an ion-exchange membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C. This membrane-electrode assembly was introduced into a single fuel cell holder so that cell H was manufactured.

Page 32 bridging page 33, 2nd paragraph:

A porous carbon paper as a substrate (0.5 mm) to which hydrophobicity was imparted by coating with PTFE suspension (Teflon 30J manufactured by Mitsui-Dupont Fluorochemical) was coated with paste including platinum supported on carbon (10V30E: 30wt% Pt supported on Valcan XC-72 manufactured by Tanaka Kikinzoku), solid polymer

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membrane (Nafion manufactured by Dupont and having a thickness of 50 μm) at 140°C. This membrane-electrode assembly was introduced into a single fuel cell holder so that cell I was manufactured.

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As can be understood from Fig. 3, the cell (H) according to the present invention exhibited output voltages higher than those of the conventional cell (I) in a high current density region. The electrode according to the present invention incorporated comprised the porous carbon substrate contains porous polymers obtained by fluorinating P(VdF-HFP). Therefore, excellent hydrophobicity and gas diffusivity were simultaneously imparted to the electrode. On the other hand, the conventional electrode incorporated comprised the porous carbon substrate coated with PTFE particles. Therefore, the conventional electrode having excellent hydrophobicity and poor gas diffusivity because the pores in the substrate were closed by PTFE particles.

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The electrode for a fuel cell according to the present invention including the porous polymer shows simultaneously excellent hydrophobicity and gas diffusivity. Furthermore, the thickness of the catalyst layer was maintained uniformly, therefore overall portion of the electrode is effective for electrochemical reactions. Hence it follows that the active area of the electrode can be enlarged as compared with that of the conventional electrode. As a result, a high-performance fuel cell can be manufactured. The manufacturing method according to the present invention is able to manufacture the electrode improving a high-performance for fuel cell can be manufactured.

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result, a ~~high~~-performance fuel cell can be manufactured. The manufacturing method according to the present invention is able to manufacture the electrode improving a high-performance for fuel cell can be manufactured.

The claims are amended as follows:

1. (Amended) An electrode for a fuel cell comprising: a catalyst layer and a porous polymer, wherein said catalyst layer containing a solid polymer electrolyte and catalyst particles.

10. (Amended) The electrode according to claim 1 ~~and~~ or 3, wherein said porous polymer is fluorocarbon polymer.

11. (Amended) A method of manufacturing porous polymer according to claim 1 or 3 comprising the step of: separating a polymer (a) from the solution (c) in which the polymer (a) is dissolved in a solvent (b) by the phase inversion process.

12. (Amended) A method of manufacturing porous polymer according to claim 1 or 3 comprising the step of: extracting a solvent (b) from the solution (c), in which a polymer (a) is dissolved in the solvent (b), with the non solvent (d) which is insoluble in the polymer (a) and miscible with the solvent (b).

13. (Amended) A method of manufacturing an electrode for a fuel cell comprising the steps of:

preparing an electrode (j) comprising a catalyst layer containing a solid polymer electrolyte and catalyst particles;

preparing a solution (c) in which a polymer (a) is dissolved in a solvent (b);

allowing said solution (c) to be contained in said electrode; and

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preparing an electrode (j) comprising a catalyst layer containing a solid polymer electrolyte and catalyst particles;

preparing a solution (c) in which a polymer (a) is dissolved in a solvent (b);

allowing said solution (c) to be contained in said electrode; and

extracting said solvent (b) from the said solution (c) with a non solvent (d) which is insoluble in said polymer (a) and miscible with the solvent (b).

20. (Amended) The method according to claim 13, 14, 17 or 18, further comprising the step of: fluorinating said porous polymer.